Complex astronomical forcing of South Asian monsoon precipitation over the past ~1 million years

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The South Asian monsoon (SAM) precipitation is vitally important for billions of people yet its controlling mechanisms are still poorly understood. Absolutely dated speleothem records from China [1] record a mixed signal of the amount of precipitation and moisture sources [2] while records of monsoon wind induced upwelling in the Arabian Sea may not be directly related to monsoon rainfall [3]. The core convective region of the SAM is over the Bay of Bengal and Andaman Sea but no records covering many of Earth's orbital cycles exist for this region. Here we reconstruct Andaman Sea surface seawater temperature and oxygen isotope compositions over the past one million years with measurements of planktic foraminifera. Our new record reveals that SAM precipitation was weakest during all glacial maxima and strong during the interglacials of the last million years. Superimposed on this were higher frequency variations and in the precession band SAM precipitation peaked ~9 kyrs after the Northern Hemisphere insolation maximum, in phase with changes in the Arabian Sea. Nonetheless, the precession band accounts for only a small component (~30%) of the total variance of SAM precipitation and thus cannot be considered the primary driving force. We show that obliquity forcing has played a much larger role and is triggered by Southern hemisphere warming and cross hemisphere moisture transport rather than Northern Hemisphere insolation. This is the first direct evidence that precipitation in the South and East Asian monsoon subsystems responded independently to changes in solar insolation.

[1] Cheng, H. et al. (2016). Nature 534, 640-646.
[2] Maher & Thompson (2012). J. Quat. Science 27, 615-624.
[3] Ziegler, M. et al. (2010). Paleoceanography 25, issue 3.